



**BIOLOGICAL INTEGRITY IN BOX ELDER CREEK
BASED ON PERIPHYTON COMPOSITION
AND COMMUNITY STRUCTURE**

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SUMMARY

In early August 1999, composite periphyton samples were collected from natural substrates at 8 sites on Box Elder Creek in central Montana. Samples were collected following MDEQ standard operating procedures, processed and analyzed using standard methods for periphyton, and evaluated following modified USEPA rapid bioassessment protocols for wadeable streams.

Box Elder Creek is an intermittent "pooled channel" stream with a silty bottom. It is classified C-3 in the Montana Surface Water Quality Standards.

Box Elder Creek supported a very diverse algal flora. The non-diatom algae indicated warm, standing waters with elevated concentrations of organic nutrients. This organic loading was probably internal and natural in origin (i.e., from decaying aquatic vegetation). Nitrogen was likely the limiting nutrient in Box Elder Creek, especially in the middle and lower reaches of the study section. In reaches 003 and 004, the presence of *Chara* indicated stable soft substrates and low levels of turbidity.

The diatom assemblages of Box Elder Creek supported the findings of organic nutrient loading and nitrogen limiting conditions, the latter particularly in the lower reaches of the study section. Diatom metrics also indicated low levels of disturbance and elevated concentrations of dissolved solids.

The relatively large percentage of motile diatoms indicated moderate levels of sedimentation in all reaches except Reach 001. Moderate impairment was indicated even in the reference reach (Reach 022), which was judged to be "proper functioning" based on the good condition of the riparian habitat. This may indicate that the sedimentation index is more responsive to channel morphology and stream type than it is to riparian condition.

INTRODUCTION

This report evaluates the support of aquatic life uses, and probable causes of impairment to those uses, in Box Elder Creek in central Montana. This evaluation is part of a larger study that is being conducted by the Riparian and Wetland Research Program of The University of Montana in cooperation with the U.S. EPA, MDEQ, BLM, and private landowners. Objectives of the study are (1) to evaluate several indicators that are used to monitor grazing levels in riparian areas, and (2) to determine if there are relationships between these indicators and water quality, riparian condition, and stream function. The goal is to be able to predict water quality using grazing use level indicators in riparian areas (RWRP Website).

Evaluation of use support in this report is based on the species composition and community structure of periphyton (benthic algae) communities at 8 stream sites that were sampled in early August 1999. The periphyton or phytobenthos community is a basic biological component of all aquatic ecosystems. Periphyton accounts for much of the primary production and biological diversity of Montana streams (Bahls et al. 1992).

Plafkin et al. (1989) and Stevenson and Bahls (1999) list several advantages of using periphyton in biological assessments of streams:

- Algae are universally present in large numbers in all streams and unimpaired periphyton assemblages typically support a large number (>30) of species;
- Algae have rapid reproduction rates and short life cycles, making them useful indicators of short-term impacts;
- As primary producers, algae are most directly affected by physical and chemical factors, such as temperature, nutrients, and toxins;

- Sampling is quick, easy and inexpensive, and causes minimal damage to resident biota and their habitat;
- Standard methods and criteria exist for evaluating the composition, structure, and biomass of algal associations;
- Identification to species is straightforward for the diatoms, for which there is a large body of taxonomic and ecological literature;
- Excessive algae growth in streams is often correctly perceived as a problem by the public.
- Periphyton and other biological communities reflect the *biological integrity*¹ of waterbodies; restoring and maintaining the biological integrity of waterbodies is a goal of the federal Clean Water Act;
- Periphyton and other biological communities integrate the effects of different stressors and provide a measure of their aggregate impact; and
- Periphyton and other biological communities may be the only practical means of evaluating impacts from non-point sources of pollution where specific ambient criteria do not exist (e.g., impacts that degrade habitat or increase nutrients).

Periphyton is a diverse assortment of simple photosynthetic organisms called algae, and other microorganisms that live attached to or in close proximity of the stream bottom. Most algae, such as the diatoms, are microscopic. Diatoms are distinguished by having a cell wall composed of opaline glass--hydrated amorphous silica. Diatoms often carpet a stream bottom with a slippery brown film.

Some algae, such as the filamentous greens, are conspicuous and their excessive growth may be aesthetically displeasing, deplete dissolved oxygen, interfere with fishing and fish

¹ *Biological integrity* is defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region" (Karr and Dudley 1981).

spawning, clog irrigation intakes, create tastes and odors in drinking water, and cause other problems.

The federal Clean Water Act directs states to develop water pollution control plans (Total Maximum Daily Loads or TMDLs) that set limits on pollution loading to water-quality limited waters. Water-quality limited waters are lakes and stream segments that do not meet water-quality standards, that is, that do not fully support their beneficial uses. The Clean Water Act and EPA regulations require each state to (1) identify waters that are water-quality limited, (2) prioritize and target waters for TMDLs, and (3) develop TMDL plans to attain and maintain water-quality standards for all water-quality limited waters.

One purpose of this report is to provide information that will help the State of Montana to determine whether Box Elder Creek is water-quality limited and in need of TMDLs. Another purpose of this report is to evaluate the sensitivity of periphyton metrics to grazing levels in riparian areas.

PROJECT AREA AND SAMPLING SITES

The project area is a section of Box Elder Creek north of Winnett in Petroleum County in central Montana. Box Elder Creek heads in the Judith Mountains northeast of Lewistown and flows southeasterly for about 70 miles to the point where it meets the Musselshell River upstream from Mosby, Montana. The watershed encompasses 1,184 square miles.

The project area is in the Central Grassland Subregion of the Northwestern Great Plains Ecoregion (Woods et al. 1999). The surface geology consists mainly of marine shales of the Colorado Group (Taylor and Ashley, undated). Upland vegetation in the study area is mixed grassland (USDA 1976). Riparian vegetation

along Box Elder Creek is dominated by graminoids and introduced herbaceous species. The sparse shrub layer is dominated by western snowberry, sandbar willow, peachleaf willow, and box elder (RWRP Website). The main land use is livestock grazing.

Elevations at the sampling sites range from about 2,940 feet at the upper site (Reach 022) to 2,860 feet at the lowest site (Reach 001). Box Elder Creek is an intermittent "pooled channel" stream with a silty bottom (Amy Chadwick, RWRP, personal communication). It is classified C-3 in the Montana Surface Water Quality Standards.

METHODS

Periphyton samples were collected from pool edges at 8 sites in early August 1999 (Table 1). Three replicate samples were collected at one of these sites (Reach 003). Reach 022 was considered to be a "properly functioning" reference reach from the standpoint of riparian habitat. The other reaches were rated "functional at risk" (Amy Chadwick, RWRP, pers. comm.).

Periphyton samples were collected following standard operating procedures of the MDEQ Planning, Prevention, and Assistance Division. Using appropriate tools, microalgae were scraped, brushed, or sucked from natural substrates in proportion to the rank of those substrates at the study site. Macroalgae were picked by hand in proportion to their abundance at the site. All collections of microalgae and macroalgae were pooled into a common container and preserved with Lugol's solution.

Samples were examined to estimate the relative abundance and rank by biovolume of diatoms and genera of soft (non-diatom) algae according to the method described in Bahls (1993). Soft algae were identified using Prescott (1978), Smith (1950), and

Whitford and Schumacher (1984). These books also served as the main references on the ecology of the soft algae.

After the identification of soft algae, raw periphyton samples were cleaned of organic matter using sulfuric acid, and permanent diatom slides were prepared in a high refractive index mounting medium following *Standard Methods for the Examination of Water and Wastewater* (APHA 1998). For each slide, between 437 and 496 diatom cells (874 to 992 valves) were counted at random and identified to species.

The following were used as the main taxonomic and autecological references for the diatoms: Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b; Patrick and Reimer 1966, 1975. Lowe (1974) was also used extensively as an ecological reference for the diatoms. Bahls et al. (1984) provide autecological information on important diatom species that live in the Southern Fort Union Coal Region of Montana, which includes many of those living in Box Elder Creek.

The diatom proportional counts were used to generate an array of diatom association metrics (Table 2). A metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al. 1999).

One additional metric was calculated for this study: percent of cells in the diatom family Epithemiaceae. This family is represented in streams by two genera, *Epithemia* and *Rhopalodia*, that commonly harbor endosymbiotic nitrogen-fixing bluegreen algae (cyanobacteria) within their cells. A diatom association that contains a large percentage of cells in these genera may indicate nitrogen-limiting conditions, that is, low nitrogen to phosphorus ratios (Stevenson and Pan 1999).

Metric values from Box Elder Creek were compared to numeric

biocriteria developed for streams in the Great Plains Ecoregions of Montana (Table 3). These criteria are based on metric values measured in least-impaired reference streams (Bahls et al. 1992) and on metric values measured in streams that are known to be impaired by various sources and causes of pollution (Bahls 1993).

The criteria in Table 3 distinguish among four levels of impairment and three levels of aquatic life use support: no impairment or only minor impairment (full support); moderate impairment (partial support); and severe impairment (nonsupport). These impairment levels correspond to excellent, good, fair, and poor *biological integrity*, respectively.

Only periphyton samples collected in summer (June 21-September 21) can be compared with confidence to reference stream samples because metric values change seasonally and summer is the season in which reference streams and impaired streams were sampled for the purpose of biocriteria development.

Quality Assurance. Several steps were taken to assure that the study results are accurate and reproducible. Upon receipt of the samples, station and sample information were recorded in a laboratory notebook and samples were assigned a unique number compatible with the Montana Diatom Database, e.g., 1885-01. The first part of this number (1885) designates the sampling site (Box Elder Creek Reach BE022); the second part of the number (01) designates the number of periphyton samples that have been collected at this site to date for which data have been entered into the Montana Diatom Database.

Sample observations and analyses of soft (non-diatom) algae were recorded in a lab notebook along with station and sample information provided by MDEQ. A portion of the raw sample was used to make duplicate diatom slides.

On completion of the project, station information, sample information, and diatom proportional count data will be entered into the Montana Diatom Database. One set of diatom slides will be deposited in the University of Montana Herbarium in Missoula. The other set of slides will be retained by *Hanna* in Helena.

RESULTS AND DISCUSSION

Results are presented in Tables 4 and 5, located near the end of this report following the Literature Cited section. Spreadsheets containing completed diatom proportional counts, with species pollution tolerance classes (PTC) and calculated percent abundances, are attached as Appendix A.

SAMPLE NOTES

Reach 022. This sample was very silty. Macrophytes were present. The *Cladophora* here was senescent and covered with epiphytes, which included *Oedogonium*, *Phormidium*, *Rivularia*, and *Stigeoclonium*. Free-living *Oedogonium* was also present. Only straight filaments of *Anabaena* were observed.

Reach 012. This sample was very silty. Macrophytes were present. Ostracods and amphipods were very abundant. Both coiled and straight filaments of *Anabaena* were observed.

Reach 011. Sample was very silty. Terrestrial vegetation was present in the sample. The *Phormidium* was epiphytic on filamentous algae.

Reach 008. Sample was silty, but not as silty as sample from Reach 006. Macrophytes were absent, but some terrestrial vegetation was included in the sample. At least four species of *Spirogyra* were present.

Reach 006. Sample was very silty and macrophytes were present. Both straight and coiled filaments of *Anabaena* were observed. Most diatoms were very small.

Reach 004. *Chara* appears here and in Reach 003. Sample not very silty. Only straight filaments of *Anabaena* were observed.

Reach 003.3. Sample not very silty; includes macrophytes. Straight and coiled filaments of *Anabaena* were observed.

Reach 003.2. Macrophytes present. Sample not very silty. Both straight and coiled filaments of *Anabaena* were present.

Reach 003.1. Sample contains little silt. The *Calothrix* species formed large gelatinous masses. More than one species of *Anabaena* was present.

Reach 001. Sample was silty and crammed with macrophytes. Multiple species of *Oedogonium*, *Mougeotia*, and *Cosmarium* were present, as well as straight and coiled species of *Anabaena*.

NON-DIATOM ALGAE

Box Elder Creek had a very diverse algal flora, even for a prairie stream (Table 4). [Prairie streams generally have more genera of non-diatom algae and more species of diatoms than do mountain streams (Bahls 1993).] Reach 022 supported 21 genera of non-diatom algae. The other sites supported fewer genera, but still had good taxonomic richness.

All sites supported green algae (Chlorophyta), euglenoid algae, chrysophytes (mostly diatoms), and cyanobacteria. Dinoflagellates (*Gonyaulax*) and Cryptomonads (*Rhodomonas*) were uncommon to common at some of the upper sites. Algae in these latter groups are typically planktonic and found in open water.

Filamentous green algae, mainly *Cladophora*, *Rhizoclonium*, and *Spirogyra*, dominated at most of the sites (Table 4). Cyanobacteria, mainly *Anabaena*, *Calothrix*, and *Lyngbya*, were also abundant, particularly at stations near the middle and lower end of the study section. Diatoms were very common to abundant at all sites (Table 4).

Certain genera of algae have rather specific environmental requirements and serve as good indicators of water quality. *Chara*, a green macroalga, requires soft but stable substrates and clear water; it does not do well in turbid water. *Chara* was found only in Reaches 004 and 003 (Table 4). The samples from these reaches were relatively free of silt (see Sample Notes, above).

A species of *Calothrix* (Division Cyanophyta) with filaments embedded in profuse gelatinous masses, was, like *Chara*, abundant only in the lower reaches of the study section (Table 4). This taxon may also be sensitive to turbid waters.

Cladophora is a branched filamentous green alga that grows best in cool, flowing water (15-23°C). In Box Elder Creek, *Cladophora* was found only in Reach 022 (Table 4). *Cladophora* is closely related to *Rhizoclonium*, which prefers standing and warmer waters (>23°C). *Rhizoclonium* was found at all sites, including Reach 022 (Table 4).

Euglena and its cohorts *Phacus* and *Trachelomonas* generally indicate elevated concentrations of organic nutrients. These algae were found throughout the study section (Table 4). Since livestock are not known to concentrate in or along Box Elder Creek (Amy Chadwick, RWRP, personal communication), this loading is probably internal and natural in origin (i.e., from decaying aquatic vegetation).

An abundance of nitrogen-fixing cyanobacteria probably indicates that nitrogen, rather than phosphorus, is the nutrient that is in shortest supply relative to the needs of the algae of Box Elder Creek, especially in the lower reaches of the study section. Box Elder Creek was unusual in that it supported three or more species of *Anabaena*, a planktonic and sometimes toxic cyanobacterium. The abundance of *Anabaena* and the presence of several other genera of planktonic algae (e.g., the euglenoid algae plus *Chlamydomonas*, *Dinobryon*, and *Scenedesmus*) reflect the pooled nature of the Box Elder Creek channel.

DIATOMS

The major diatom species in Box Elder Creek are somewhat to very tolerant of organic pollution and nutrient enrichment (Class 2 and 1 diatoms, respectively; Table 5). *Nitzschia palea* is a nitrogen heterotroph, meaning that it can assimilate and utilize forms of organic nitrogen. Some of these major species (e.g., *Nitzschia filiformis*, *Nitzschia reversa*, and *Synedra fasciculata*) also indicate elevated concentrations of dissolved solids.

Diatom diversity and species richness were normal for a prairie stream, with only minor impairment indicated in Reaches 004 and 003 (Table 5). The pollution index indicated minor impairment at most sites, but moderate impairment in Reaches 006 and 001. The pollution index responds mostly to organic loading (Lange-Bertalot 1979). In Box Elder Creek, this loading is probably internal and natural in origin, resulting from the fertile, intermittent nature of the stream, its pooled channel morphology, and its low frequency of flushing.

The sedimentation index, which is the percentage of motile diatoms, indicated moderate impairment at all sites except Reach 001, where only minor impairment was indicated (Table 5). The sedimentation index indicated moderate impairment even in the reference reach (Reach 022), which was judged to be "proper functioning" based on the relatively good condition of the riparian habitat here (Amy Chadwick, RWRP, pers. comm.). This may indicate that the sedimentation index is more responsive to channel morphology and stream type than it is to the condition of the riparian area.

The disturbance index was uniformly low at all sites on Box Elder Creek (Table 5). The disturbance index is based on the percent abundance of *Achnanthes minutissima*, which is a pioneer species that colonizes disturbed habitats. The relatively low numbers of this taxon indicate that Box Elder Creek supported a mature algal assemblage and that there had been little physical, chemical or biological disturbance to the periphyton in the days and weeks prior to sampling.

The dominant diatom species at each site generally accounted for less than 25% of the cells (Table 5). The only exceptions were in Reaches 006 and 003, where *Nitzschia palea* and *Nitzschia frustulum*, respectively, accounted for slightly more than a quarter of the cells. This relatively low percent dominance and

the good equitability of diatom cells among species indicated only minor impairment at these sites.

Slightly more than 1% of the diatom cells in the sample from Reach 011 were abnormal in shape (Table 5). Smaller percentages of abnormal cells were counted in Reaches 008, 006, and 003. Among the causes of teratological deformities in diatom cells are toxins and salinity. Healthy diatom assemblages typically do not have abnormal cells, except for natural monstrosities represented by post-auxospore cells (*Erstlingzelle*). In mountain streams, heavy metals may produce deformities, particularly among the Fragilariaceae (McFarland et al. 1997). The cause of the abnormal cells in Box Elder Creek is unknown.

Representatives of the diatom family Epithemiaceae were present at all of the Box Elder Creek sites (Table 5). Diatoms in this family harbor endosymbiotic nitrogen-fixing cyanobacteria within their cells and are usually most abundant where nitrogen is the limiting nutrient. The percentage of diatoms in this family peaked in Reaches 003 and 001 at the downstream end of the study section.

The similarity index indicates floristic affinities between adjacent reaches. It can be used to judge the degree of change in water quality and other variables between sites. The most dissimilar adjacent reaches were 011 and 012, followed by 012 and 022 (Table 5). In fact, reaches 022 and 001 had about as much in common, floristically, as did reaches 022 and 012. On the other hand, reaches 008 and 011 were very similar, as were reaches 001 and 003, and 003 and 004 (Table 5). The duplicate samples from Reach 003 approached 80% similarity, which is to be expected for duplicate samples from the same site (Bahls 1993).

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Table 1. Location of periphyton sampling stations on Box Elder Creek: RWRP reach identification number, sample number in the Montana Diatom Database, site elevation, legal description, and sample date. Sites are listed in order from upstream to downstream. All sites are located in USGS Hydrologic Unit 10040204 (Box Elder Creek).

Reach ID Number	Sample Number	Elevation (feet)	Legal Description	Sample Date
BE022	1885-01	2,940	T16NR26E06C	08/09/1999
BE012	1884-01	2,920	T16NR26E21A/22B	08/08/1999
BE011	1883-01	2,920	T16NR26E22C	08/08/1999
BE008	1882-01	2,900	T16NR26E26B/27A	08/08/1999
BE006	1881-01	2,900	T16NR26E35A/D	08/08/1999
BE004	1880-01	2,880	T16NR26E36CD	08/08/1999
BE003.3	1879-01	2,880	T16NR26E36DC	08/08/1999
BE003.2	1878-01	2,880	T16NR26E36DC	08/08/1999
BE003.1	1877-01	2,880	T16NR26E36DC	08/08/1999
BE001	1876-01	2,860	T15NR27E06	08/08/1999

Table 2. Diatom association metrics used to evaluate biological integrity in Montana streams: reference, range of values in Montana streams, and expected direction of metric response to increasing anthropogenic perturbation or natural stress.

Metric	Reference	Range of Values	Expected Response
Shannon Species Diversity	Bahls 1979	0.00-5.00+	Decrease ¹
Pollution Index ²	Bahls 1993	1.00-3.00	Decrease
Siltation Index ³	Bahls 1993	0.00-90.0+	Increase
Disturbance Index ⁴	Barbour et al. 1999	0.00-100.0	Increase
No. Species Counted	Bahls 1979, 1993	0-100+	Decrease ¹
Percent Dominant Species	Barbour et al. 1999	5.0-100.0	Increase
Percent Abnormal Cells	McFarland et al. 1997	0.0-20.0+	Increase
Similarity Index	Whittaker 1952	0.0-80.0+	Decrease

¹ Shannon diversity and species richness may increase somewhat in naturally nutrient-poor mountain streams in response to slight to moderate increases in nutrients or sediment.

² This is a composite numeric expression of the pollution tolerances assigned by Lange-Bertalot (1979) to the common diatom species.

³ Computed as the sum of the percent abundances of all species in the genera *Navicula*, *Nitzschia*, and *Surirella*. These are common genera of predominantly motile taxa that are able to maintain their positions on the substrate surface in depositional environments.

⁴ Computed as the percent abundance of *Achnanthes minutissima*. This attached taxon typically dominates early successional stages of benthic diatom associations and resists chemical, physical and biological disturbances in the form of metals toxicity, substrate scour by high flows and fast currents, and grazing by macroinvertebrates.

Table 3. Criteria for rating levels of biological integrity, environmental impairment or natural stress, and aquatic life use support in Wadeable Plains streams of Montana using selected metrics for benthic diatom associations. The lowest rating for any one metric is the overall rating for the study site.

Biological Integrity/ Impairment or Natural Stress/Use Support	Diversity Index (Shannon)	Pollution Index	Siltation Index	Disturbance Index	Number of Species Counted	Percent Dominant Species	Percent Abnormal Cells	Percent Similarity Index ¹
Excellent None/Full Support	>3.99	>2.25	<50.0	<25.0	>39	<25.0	0.0	>59.9
Good/Minor Full Support	3.00- 3.99	1.76- 2.25	50.0- 69.9	25.0- 49.9	30- 39	25.0 49.9	>0.0- <1.0	40.0- 59.9
Fair/Moderate Partial Support	2.00- 2.99	1.25- 1.75	70.0- 89.9	50.0- 74.9	20- 29	50.0- 74.9	1.0- 9.9	20.0- 39.9
Poor/Severe Nonsupport	<2.00	<1.25	>89.9	>74.9	<20	>74.9	>9.9	<20.0

¹ The Similarity Index or Percent Community Similarity (Whittaker 1952) may be used to compare a study site to an unimpacted upstream control site on the same stream. This metric measures the degree of floristic similarity between diatom associations at the two sites and is the sum of the smaller of the two percent abundance values for each species that is common to both sites. Adjacent riffles on the same stream, without intervening tributaries or environmental perturbations, will generally have at least 60% of their diatom floras in common (Bahls 1993). PCS may also be used to gauge the relative amount of impairment or recovery that occurs between adjacent study sites: >59.9% = very similar floras, no change; 40.0-59.9% = somewhat similar floras, minor change; 20.0-39.9% = somewhat dissimilar floras, moderate change; <20.0% = very dissimilar floras, major change.

Table 4. Estimated relative abundance of algal cells and rank by volume of diatoms and genera of non-diatom algae in periphyton samples collected from Box Elder Creek in August 1999. Sites and data are listed in order from upstream to downstream, left to right. R = rare, U = uncommon, C = common, VC = very common, A = abundant, VA = very abundant.

Taxa	022	012	011	008	006	004	003.3	003.2	003.1	001
Chlorophyta										
Ankistrodesmus	U(16)	U(12)								C(11)
Bulbochaete	R					R			R	
Chara					R	C(5)	A(3)	A(2)	A(3)	
Chlamydomonas							A(6)	VC(6)	VC(7)	
Cladophora	VA(1)									
Closterium		U(9)	U(12)		U(8)	R				R
Cosmarium	R	R	R		R	R			C(9)	U(9)
Microspora	U(12)	U(8)	C(8)	U(8)	C(7)			VC(9)		C(8)
Mougeotia	R				U(9)	VA(1)	R			VA(2)
Oedogonium	A(4)	VC(4)	A(3)	A(2)	C(6)	U(10)		C(11)		VC(6)
Rhizoclonium	VA(2)	VA(1)	VA(2)	VC(5)	VA(1)	C(8)	VA(1)	VA(1)	VA(1)	VA(1)
Scenedesmus	C(13)		R	R	U(12)			R	R	R
Spirogyra	A(3)	VA(2)	VA(1)	VA(1)	VA(2)	A(2)	U(8)	VC(8)	U(10)	U(10)
Stigeoclonium	C(7)									
Euglenophyta										
Euglena	R	U(11)	U(13)	C(7)		U(9)	C(9)	VC(7)	C(8)	U(12)
Phacus		R			R					
Trachelomonas		R						R		
Chrysophyta										
Diatoms	VC(5)	A(3)	VC(5)	VC(4)	VC(4)	VC(6)	VC(7)	A(5)	A(5)	VC(5)
Dinobryon				R	U(11)					
Tribonema					U(10)					
Pyrrrophyta										
Gonyaulax	U(14)	U(10)	C(11)	C(6)						R

Table 4. Continued...

Taxa	Reach									
	022	012	011	008	006	004	003.3	003.2	003.1	001
Cyanophyta										
<i>Amphithrix</i>	U(15)			U(9)	VC(5)	VC(7)	VA(2)	R	R	U(13)
<i>Anabaena</i>	C(11)	C(6)	C(7)			A(4)	A(5)	A(4)	A(4)	A(3)
<i>Calothrix</i>								A(3)	VA(2)	A(4)
<i>Chroococcus</i>										R
<i>Coelosphaerium</i>										R
<i>Hydrocoleum</i>	C(10)									
<i>Lyngbya</i>		C(5)	A(4)	A(3)	VA(3)	A(3)	A(4)	C(10)	VC(6)	C(7)
<i>Merismopedia</i>					R		R		R	U(14)
<i>Nodularia</i>	C(9)		C(9)							
<i>Oscillatoria</i>	C(8)	C(7)		R			R			
<i>Phormidium</i>	C(6)	U(13)	VC(6)							
<i>Rivularia</i>	R									
<i>Spirulina</i>					R		R	R	R	
Cryptophyta										
<i>Rhodomonas</i>			U(14)	U(10)						

Table 5. Percent abundance of major diatom species¹ and values of selected diatom association metrics for periphyton samples collected from Box Elder Creek in August 1999. Underlined values indicate full support of aquatic life uses with minor impairment; **bold values** indicate partial support of aquatic life uses with moderate impairment; all other values indicate full support of aquatic life uses and no impairment based on the ecoregional reference stream approach (Protocol I in Bahls 1993) and criteria for wadeable prairie streams in Table 3.

Species/Metric (Pollution Tolerance Class)	Reach										
	022	012	011	008	006	004	003.3	003.2	003.1	001	
<i>Mitzschia filiformis</i> (2)	2.6	13.9	1.1	0.3							
<i>Mitzschia frustulum</i> (2)	14.2	7.1	18.5	16.5	10.3	24.7	25.3	20.7	23.9	20.1	
<i>Mitzschia palea</i> (1)	18.9	8.4	10.6	16.6	29.1	16.3	19.9	14.5	22.0	23.5	
<i>Mitzschia paleacea</i> (2)	8.7	6.8	8.9	13.5	12.4	24.1	7.2	11.1	6.4	1.8	
<i>Mitzschia reversa</i> (2)	6.6	19.3	2.4	2.8	0.8	2.8	5.6	7.7	9.9	4.2	
<i>Synedra fasciculata</i> (2)	2.0	5.1	7.2	3.7	3.5	3.9	6.8	9.8	4.6	11.8	
Number of Cells Counted	458	457	456	490	496	460	482	470	466	437	
Shannon Species Diversity	4.32	4.37	4.49	4.29	4.17	3.70	3.99	4.10	3.94	4.04	
Pollution Index	<u>1.86</u>	<u>1.95</u>	<u>1.90</u>	<u>1.79</u>	1.62	<u>1.83</u>	<u>1.80</u>	<u>1.83</u>	<u>1.76</u>	1.68	
Siltation Index	78.5	76.9	73.5	84.2	76.7	85.3	77.8	79.1	85.3	<u>67.7</u>	
Disturbance Index	6.0	1.2	3.8	3.2	1.0	0.6	0.2	0.2	0.0	0.5	
Number of Species Counted	54	54	59	60	63	55	50	50	53	55	
Percent Dominant Species	18.9	19.3	18.5	16.6	29.1	24.7	25.3	20.7	23.9	23.5	
Percent Abnormal Cells	0.0	0.0	1.3	<u>0.8</u>	<u>0.6</u>	0.0	0.0	<u>0.2</u>	0.0	0.0	
Percent Epithemiaeae	2.6	3.2	1.8	1.5	0.6	1.8	5.8	3.8	3.6	4.0	
Similarity Index ³	52.6	51.5	72.1	59.8	61.0	70.6	79.3	78.3	71.7		

¹ A major diatom species is here considered to be one that accounts for 10.0 percent or more of the diatom cells that were counted at one or more stations in a sample set.

² A "p" indicates that the species was observed as present during a floristic scan of the slide but was not encountered during the diatom proportional count.

³ The similarity index between Reach 001 and Reach 022 was 52.0.

APPENDIX A: DIATOM PROPORTIONAL COUNTS

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
187601	<i>Achnanthes minutissima</i>	3	4	0.46
187601	<i>Amphora coffeaeformis</i>	1	2	0.23
187601	<i>Amphora veneta</i>	1	5	0.57
187601	<i>Bacillaria paradoxa</i>	2	0	0.00
187601	<i>Caloneis bacillum</i>	2	2	0.23
187601	<i>Chaetoceros muelleri</i>	1	1	0.11
187601	<i>Cocconeis placentula</i>	3	4	0.46
187601	<i>Cyclotella meneghiniana</i>	2	43	4.92
187601	<i>Cymbella pusilla</i>	1	20	2.29
187601	<i>Diploneis puella</i>	2	6	0.69
187601	<i>Entomoneis paludosa</i>	2	4	0.46
187601	<i>Epithemia adnata</i>	2	22	2.52
187601	<i>Epithemia sorex</i>	3	0	0.00
187601	<i>Epithemia turgida</i>	3	0	0.00
187601	<i>Gomphonema clavatum</i>	2	1	0.11
187601	<i>Gomphonema parvulum</i>	1	14	1.60
187601	<i>Gyrosigma spencerii</i>	2	0	0.00
187601	<i>Mastogloia smithii</i>	2	1	0.11
187601	<i>Navicula capitata</i>	2	2	0.23
187601	<i>Navicula caterva</i>	2	17	1.95
187601	<i>Navicula circumtexta</i>	1	3	0.34
187601	<i>Navicula erifuga</i>	2	7	0.80
187601	<i>Navicula goersii</i>	2	2	0.23
187601	<i>Navicula gregaria</i>	2	18	2.06
187601	<i>Navicula halophila</i>	2	2	0.23
187601	<i>Navicula peregrina</i>	2	3	0.34
187601	<i>Navicula reichardtiana</i>	2	0	0.00
187601	<i>Navicula rhynchocephala</i>	2	1	0.11
187601	<i>Navicula salinicola</i>	1	6	0.69
187601	<i>Navicula slesvicensis</i>	2	2	0.23
187601	<i>Navicula tenelloides</i>	1	2	0.23
187601	<i>Navicula tenera</i>	1	0	0.00
187601	<i>Navicula vandamii</i>	2	4	0.46
187601	<i>Navicula veneta</i>	1	9	1.03
187601	<i>Nitzschia acicularis</i>	2	6	0.69
187601	<i>Nitzschia apiculata</i>	2	4	0.46
187601	<i>Nitzschia archibaldii</i>	2	10	1.14
187601	<i>Nitzschia aurariae</i>	1	2	0.23
187601	<i>Nitzschia capitellata</i>	2	2	0.23
187601	<i>Nitzschia dissipata</i>	3	4	0.46
187601	<i>Nitzschia flexa</i>	2	0	0.00
187601	<i>Nitzschia frustulum</i>	2	176	20.14
187601	<i>Nitzschia inconspicua</i>	2	1	0.11
187601	<i>Nitzschia levidensis</i>	2	2	0.23
187601	<i>Nitzschia liebetruthii</i>	2	8	0.92
187601	<i>Nitzschia microcephala</i>	1	13	1.49
187601	<i>Nitzschia palea</i>	1	205	23.46
187601	<i>Nitzschia paleacea</i>	2	16	1.83
187601	<i>Nitzschia reversa</i>	2	37	4.23
187601	<i>Nitzschia sigma</i>	1	1	0.11
187601	<i>Nitzschia sociabilis</i>	2	18	2.06
187601	<i>Nitzschia valdestriata</i>	2	8	0.92
187601	<i>Pinnularia microstauron</i>	2	2	0.23
187601	<i>Pleurosigma delicatulum</i>	2	2	0.23
187601	<i>Rhoicosphenia curvata</i>	3	2	0.23
187601	<i>Rhopalodia brebissonii</i>	1	3	0.34
187601	<i>Rhopalodia gibba</i>	2	1	0.11
187601	<i>Rhopalodia gibberula</i>	2	0	0.00
187601	<i>Rhopalodia operculata</i>	1	9	1.03
187601	<i>Stephanodiscus hantzschii</i>	2	5	0.57

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
187601	<i>Surirella brebissonii</i>	2	1	0.11
187601	<i>Synedra fasciculata</i>	2	103	11.78
187601	<i>Synedra pulchella</i>	2	25	2.86

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
187701	<i>Amphora libyca</i>	3	2	0.21
187701	<i>Amphora veneta</i>	1	9	0.97
187701	<i>Bacillaria paradoxa</i>	2	0	0.00
187701	<i>Caloneis bacillum</i>	2	7	0.75
187701	<i>Caloneis silicula</i>	2	2	0.21
187701	<i>Chaetoceros muelleri</i>	1	1	0.11
187701	<i>Cocconeis placentula</i>	3	6	0.64
187701	<i>Cyclotella meneghiniana</i>	2	8	0.86
187701	<i>Cylindrotheca gracilis</i>	2	2	0.21
187701	<i>Cymbella pusilla</i>	1	5	0.54
187701	<i>Diploneis puella</i>	2	3	0.32
187701	<i>Entomoneis paludosa</i>	2	0	0.00
187701	<i>Epithemia adnata</i>	2	14	1.50
187701	<i>Epithemia sorex</i>	3	8	0.86
187701	<i>Gomphonema parvulum</i>	1	6	0.64
187701	<i>Gyrosigma macrum</i>	2	1	0.11
187701	<i>Navicula capitata</i>	2	1	0.11
187701	<i>Navicula caterva</i>	2	22	2.36
187701	<i>Navicula circumtexta</i>	1	7	0.75
187701	<i>Navicula cuspidata</i>	2	2	0.21
187701	<i>Navicula erifuga</i>	2	8	0.86
187701	<i>Navicula goersii</i>	2	6	0.64
187701	<i>Navicula gregaria</i>	2	18	1.93
187701	<i>Navicula halophila</i>	2	0	0.00
187701	<i>Navicula pygmaea</i>	2	6	0.64
187701	<i>Navicula salinarum</i>	1	0	0.00
187701	<i>Navicula salinicola</i>	1	5	0.54
187701	<i>Navicula tenelloides</i>	1	0	0.00
187701	<i>Navicula tenera</i>	1	4	0.43
187701	<i>Navicula vandamii</i>	2	5	0.54
187701	<i>Navicula veneta</i>	1	3	0.32
187701	<i>Nitzschia acicularis</i>	2	1	0.11
187701	<i>Nitzschia angustatula</i>	2	1	0.11
187701	<i>Nitzschia apiculata</i>	2	1	0.11
187701	<i>Nitzschia archibaldii</i>	2	25	2.68
187701	<i>Nitzschia bergii</i>	1	0	0.00
187701	<i>Nitzschia dissipata</i>	3	7	0.75
187701	<i>Nitzschia frustulum</i>	2	223	23.93
187701	<i>Nitzschia gracilis</i>	2	4	0.43
187701	<i>Nitzschia inconspicua</i>	2	3	0.32
187701	<i>Nitzschia liebetruthii</i>	2	36	3.86
187701	<i>Nitzschia linearis</i>	2	2	0.21
187701	<i>Nitzschia microcephala</i>	1	2	0.21
187701	<i>Nitzschia palea</i>	1	205	22.00
187701	<i>Nitzschia paleacea</i>	2	60	6.44
187701	<i>Nitzschia pusilla</i>	1	2	0.21
187701	<i>Nitzschia reversa</i>	2	92	9.87
187701	<i>Nitzschia sigma</i>	2	0	0.00
187701	<i>Nitzschia sociabilis</i>	2	30	3.22
187701	<i>Nitzschia valdecostata</i>	2	0	0.00
187701	<i>Nitzschia valdestriata</i>	2	1	0.11
187701	<i>Pleurosigma delicatulum</i>	2	1	0.11
187701	<i>Rhoicosphenia curvata</i>	3	7	0.75
187701	<i>Rhopalodia brebissonii</i>	1	4	0.43
187701	<i>Rhopalodia gibba</i>	2	4	0.43
187701	<i>Rhopalodia operculata</i>	1	4	0.43
187701	<i>Stauroneis tackei</i>	2	5	0.54
187701	<i>Stephanodiscus hantzschii</i>	2	1	0.11
187701	<i>Surirella brebissonii</i>	2	13	1.39
187701	<i>Synedra fasciculata</i>	2	43	4.61

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
187701	<i>Synedra pulchella</i>	2	3	0.32

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
187801	<i>Achnanthes minutissima</i>	3	2	0.21
187801	<i>Amphora veneta</i>	1	9	0.96
187801	<i>Caloneis bacillum</i>	2	7	0.74
187801	<i>Chaetoceros muelleri</i>	1	1	0.11
187801	<i>Cocconeis placentula</i>	3	11	1.17
187801	<i>Cyclotella meneghiniana</i>	2	4	0.43
187801	<i>Cymbella pusilla</i>	1	4	0.43
187801	<i>Entomoneis alata</i>	2	1	0.11
187801	<i>Epithemia adnata</i>	2	19	2.02
187801	<i>Epithemia soresx</i>	3	9	0.96
187801	<i>Gomphonema parvulum</i>	1	8	0.85
187801	<i>Navicula capitata</i>	2	1	0.11
187801	<i>Navicula caterva</i>	2	32	3.40
187801	<i>Navicula circumtexta</i>	1	2	0.21
187801	<i>Navicula erifuga</i>	2	8	0.85
187801	<i>Navicula goersii</i>	2	6	0.64
187801	<i>Navicula gregaria</i>	2	10	1.06
187801	<i>Navicula halophila</i>	2	5	0.53
187801	<i>Navicula minuscula</i>	1	2	0.21
187801	<i>Navicula salinarum</i>	1	4	0.43
187801	<i>Navicula salinicola</i>	1	10	1.06
187801	<i>Navicula slesvicensis</i>	2	4	0.43
187801	<i>Navicula tenera</i>	1	3	0.32
187801	<i>Navicula vandamii</i>	2	3	0.32
187801	<i>Navicula veneta</i>	1	4	0.43
187801	<i>Nitzschia apiculata</i>	2	3	0.32
187801	<i>Nitzschia archibaldii</i>	2	48	5.11
187801	<i>Nitzschia aurariae</i>	1	2	0.21
187801	<i>Nitzschia capitellata</i>	2	4	0.43
187801	<i>Nitzschia dissipata</i>	3	11	1.17
187801	<i>Nitzschia frustulum</i>	2	195	20.74
187801	<i>Nitzschia levidensis</i>	2	1	0.11
187801	<i>Nitzschia liebetruthii</i>	2	28	2.98
187801	<i>Nitzschia microcephala</i>	1	16	1.70
187801	<i>Nitzschia palea</i>	1	136	14.47
187801	<i>Nitzschia paleacea</i>	2	104	11.06
187801	<i>Nitzschia reversa</i>	2	72	7.66
187801	<i>Nitzschia siliqua</i>	2	2	0.21
187801	<i>Nitzschia sociabilis</i>	2	13	1.38
187801	<i>Nitzschia valdecostata</i>	2	2	0.21
187801	<i>Nitzschia valdestriata</i>	2	3	0.32
187801	<i>Pinnularia microstauron</i>	2	2	0.21
187801	<i>Rhoicosphenia curvata</i>	3	13	1.38
187801	<i>Rhopalodia brebissonii</i>	1	2	0.21
187801	<i>Rhopalodia gibba</i>	2	5	0.53
187801	<i>Rhopalodia operculata</i>	1	1	0.11
187801	<i>Stauroneis tackei</i>	2	2	0.21
187801	<i>Surirella brebissonii</i>	2	10	1.06
187801	<i>Synedra fasciculata</i>	2	92	9.79
187801	<i>Synedra pulchella</i>	2	3	0.32

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
187901	<i>Achnanthes delicatula</i>	2	3	0.31
187901	<i>Achnanthes minutissima</i>	3	2	0.21
187901	<i>Amphora libyca</i>	3	1	0.10
187901	<i>Amphora veneta</i>	1	3	0.31
187901	<i>Caloneis bacillum</i>	2	6	0.62
187901	<i>Chaetoceros muelleri</i>	1	2	0.21
187901	<i>Cocconeis placentula</i>	3	8	0.83
187901	<i>Cyclotella atomus</i>	2	2	0.21
187901	<i>Cyclotella meneghiniana</i>	2	3	0.31
187901	<i>Cymbella pusilla</i>	1	2	0.21
187901	<i>Diploneis puella</i>	2	6	0.62
187901	<i>Entomoneis paludosa</i>	2	2	0.21
187901	<i>Epithemia adnata</i>	2	22	2.28
187901	<i>Epithemia sorex</i>	3	26	2.70
187901	<i>Gomphonema parvulum</i>	1	19	1.97
187901	<i>Gyrosigma spencerii</i>	2	2	0.21
187901	<i>Navicula capitata</i>	2	4	0.41
187901	<i>Navicula caterva</i>	2	13	1.35
187901	<i>Navicula circumtexta</i>	1	7	0.73
187901	<i>Navicula erifuga</i>	2	7	0.73
187901	<i>Navicula goersii</i>	2	6	0.62
187901	<i>Navicula gregaria</i>	2	18	1.87
187901	<i>Navicula omissa</i>	1	1	0.10
187901	<i>Navicula salinicola</i>	1	10	1.04
187901	<i>Navicula vandamii</i>	2	10	1.04
187901	<i>Navicula veneta</i>	1	2	0.21
187901	<i>Nitzschia apiculata</i>	2	3	0.31
187901	<i>Nitzschia archibaldii</i>	2	22	2.28
187901	<i>Nitzschia aurariae</i>	1	4	0.41
187901	<i>Nitzschia compressa</i>	1	2	0.21
187901	<i>Nitzschia dissipata</i>	3	13	1.35
187901	<i>Nitzschia frustulum</i>	2	244	25.31
187901	<i>Nitzschia liebetruthii</i>	2	28	2.90
187901	<i>Nitzschia microcephala</i>	1	6	0.62
187901	<i>Nitzschia palea</i>	1	192	19.92
187901	<i>Nitzschia paleacea</i>	2	69	7.16
187901	<i>Nitzschia perspicua</i>	1	8	0.83
187901	<i>Nitzschia reversa</i>	2	54	5.60
187901	<i>Nitzschia siliqua</i>	2	2	0.21
187901	<i>Nitzschia sociabilis</i>	2	15	1.56
187901	<i>Pinnularia microstauron</i>	2	1	0.10
187901	<i>Pleurosigma delicatulum</i>	2	1	0.10
187901	<i>Rhoicosphenia curvata</i>	3	18	1.87
187901	<i>Rhopalodia brebissonii</i>	1	5	0.52
187901	<i>Rhopalodia gibba</i>	2	2	0.21
187901	<i>Rhopalodia operculata</i>	1	1	0.10
187901	<i>Stephanodiscus hantzschii</i>	2	2	0.21
187901	<i>Surirella brebissonii</i>	2	10	1.04
187901	<i>Synedra fasciculata</i>	2	66	6.85
187901	<i>Synedra pulchella</i>	2	9	0.93

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188001	<i>Achnanthes delicatula</i>	2	1	0.11
188001	<i>Achnanthes minutissima</i>	3	6	0.65
188001	<i>Amphora veneta</i>	1	3	0.33
188001	<i>Bacillaria paradoxa</i>	2	1	0.11
188001	<i>Caloneis bacillum</i>	2	4	0.43
188001	<i>Chaetoceros muelleri</i>	1	1	0.11
188001	<i>Cocconeis placentula</i>	3	5	0.54
188001	<i>Cyclotella meneghiniana</i>	2	17	1.85
188001	<i>Cylindrotheca gracilis</i>	2	0	0.00
188001	<i>Cymbella pusilla</i>	1	0	0.00
188001	<i>Diploneis puella</i>	2	8	0.87
188001	<i>Entomoneis paludosa</i>	2	3	0.33
188001	<i>Epithemia adnata</i>	2	2	0.22
188001	<i>Epithemia sorex</i>	3	9	0.98
188001	<i>Epithemia turgida</i>	3	1	0.11
188001	<i>Fragilaria elliptica</i>	2	7	0.76
188001	<i>Navicula capitata</i>	2	1	0.11
188001	<i>Navicula caterva</i>	2	16	1.74
188001	<i>Navicula erifuga</i>	2	2	0.22
188001	<i>Navicula goersii</i>	2	6	0.65
188001	<i>Navicula gregaria</i>	2	25	2.72
188001	<i>Navicula halophila</i>	2	3	0.33
188001	<i>Navicula omissa</i>	1	2	0.22
188001	<i>Navicula pelliculosa</i>	1	4	0.43
188001	<i>Navicula radiosa</i>	3	2	0.22
188001	<i>Navicula salinarum</i>	1	1	0.11
188001	<i>Navicula salinicola</i>	1	4	0.43
188001	<i>Navicula tenera</i>	1	0	0.00
188001	<i>Navicula vandamii</i>	2	8	0.87
188001	<i>Navicula veneta</i>	1	10	1.09
188001	<i>Nitzschia acicularis</i>	2	4	0.43
188001	<i>Nitzschia angustatula</i>	2	0	0.00
188001	<i>Nitzschia apiculata</i>	2	2	0.22
188001	<i>Nitzschia archibaldii</i>	2	17	1.85
188001	<i>Nitzschia aurariae</i>	1	2	0.22
188001	<i>Nitzschia capitellata</i>	2	0	0.00
188001	<i>Nitzschia dissipata</i>	3	8	0.87
188001	<i>Nitzschia filiformis</i>	2	0	0.00
188001	<i>Nitzschia fonticola</i>	3	2	0.22
188001	<i>Nitzschia frustulum</i>	2	227	24.67
188001	<i>Nitzschia gracilis</i>	2	10	1.09
188001	<i>Nitzschia hungarica</i>	2	2	0.22
188001	<i>Nitzschia inconspicua</i>	2	4	0.43
188001	<i>Nitzschia liebetruthii</i>	2	16	1.74
188001	<i>Nitzschia microcephala</i>	1	4	0.43
188001	<i>Nitzschia nana</i>	2	1	0.11
188001	<i>Nitzschia palea</i>	1	150	16.30
188001	<i>Nitzschia paleacea</i>	2	222	24.13
188001	<i>Nitzschia reversa</i>	2	26	2.83
188001	<i>Nitzschia siliqua</i>	2	0	0.00
188001	<i>Nitzschia solita</i>	1	2	0.22
188001	<i>Nitzschia valdestriata</i>	2	2	0.22
188001	<i>Pleurosigma delicatulum</i>	2	3	0.33
188001	<i>Rhopalodia gibba</i>	2	2	0.22
188001	<i>Rhopalodia operculata</i>	1	2	0.22
188001	<i>Stauroneis tackei</i>	2	6	0.65
188001	<i>Stephanodiscus hantzschii</i>	2	1	0.11
188001	<i>Stephanodiscus minutulus</i>	2	1	0.11
188001	<i>Surirella brebissonii</i>	2	0	0.00
188001	<i>Synedra delicatissima</i>	2	8	0.87

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188001	<i>Synedra famelica</i>	2	4	0.43
188001	<i>Synedra fasciculata</i>	2	36	3.91
188001	<i>Synedra puichella</i>	2	0	0.00
188001	<i>Thalassiosira pseudonana</i>	2	4	0.43

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188101	<i>Achnanthes delicatula</i>	2	5	0.50
188101	<i>Achnanthes lanceolata</i>	2	3	0.30
188101	<i>Achnanthes minutissima</i>	3	10	1.01
188101	<i>Amphora veneta</i>	1	4	0.40
188101	<i>Bacillaria paradoxa</i>	2	0	0.00
188101	<i>Caloneis bacillum</i>	2	3	0.30
188101	<i>Caloneis</i> sp.	3	1	0.10
188101	<i>Chaetoceros muelleri</i>	1	35	3.53
188101	<i>Cocconeis placentula</i>	3	1	0.10
188101	<i>Cyclotella atomus</i>	2	1	0.10
188101	<i>Cyclotella meneghiniana</i>	2	34	3.43
188101	<i>Cylindrotheca gracilis</i>	2	2	0.20
188101	<i>Cymbella pusilla</i>	1	4	0.40
188101	<i>Diatoma tenue</i>	2	2	0.20
188101	<i>Diploneis puella</i>	2	6	0.60
188101	<i>Entomoneis alata</i>	2	0	0.00
188101	<i>Entomoneis paludosa</i>	2	2	0.20
188101	<i>Epithemia adnata</i>	2	0	0.00
188101	<i>Epithemia sorex</i>	3	3	0.30
188101	<i>Fragilaria elliptica</i>	2	40	4.03
188101	<i>Gomphonema parvulum</i>	1	2	0.20
188101	<i>Gyrosigma macrum</i>	2	3	0.30
188101	<i>Gyrosigma spencerii</i>	2	3	0.30
188101	<i>Navicula capitata</i>	2	1	0.10
188101	<i>Navicula caterva</i>	2	4	0.40
188101	<i>Navicula cincta</i>	1	1	0.10
188101	<i>Navicula circumtexta</i>	1	4	0.40
188101	<i>Navicula cryptotenella</i>	2	1	0.10
188101	<i>Navicula erifuga</i>	2	13	1.31
188101	<i>Navicula goersii</i>	2	30	3.02
188101	<i>Navicula gregaria</i>	2	29	2.92
188101	<i>Navicula halophila</i>	2	1	0.10
188101	<i>Navicula minuscula</i>	1	6	0.60
188101	<i>Navicula muralis</i>	1	18	1.81
188101	<i>Navicula omissa</i>	1	2	0.20
188101	<i>Navicula pygmaea</i>	2	0	0.00
188101	<i>Navicula salinicola</i>	1	7	0.71
188101	<i>Navicula slesvicensis</i>	2	1	0.10
188101	<i>Navicula tenelloides</i>	1	3	0.30
188101	<i>Navicula tenera</i>	1	4	0.40
188101	<i>Navicula vandamii</i>	2	6	0.60
188101	<i>Navicula veneta</i>	1	19	1.92
188101	<i>Nitzschia angustatula</i>	2	1	0.10
188101	<i>Nitzschia apiculata</i>	2	2	0.20
188101	<i>Nitzschia archibaldii</i>	2	24	2.42
188101	<i>Nitzschia aurariae</i>	1	2	0.20
188101	<i>Nitzschia capitellata</i>	2	8	0.81
188101	<i>Nitzschia compressa</i>	1	1	0.10
188101	<i>Nitzschia dissipata</i>	3	4	0.40
188101	<i>Nitzschia frustulum</i>	2	102	10.28
188101	<i>Nitzschia gracilis</i>	2	4	0.40
188101	<i>Nitzschia inconspicua</i>	2	0	0.00
188101	<i>Nitzschia leistikowii</i>	2	0	0.00
188101	<i>Nitzschia levidensis</i>	2	4	0.40
188101	<i>Nitzschia liebetruthii</i>	2	13	1.31
188101	<i>Nitzschia microcephala</i>	1	5	0.50
188101	<i>Nitzschia palea</i>	1	289	29.13
188101	<i>Nitzschia paleacea</i>	2	123	12.40
188101	<i>Nitzschia reversa</i>	2	8	0.81
188101	<i>Nitzschia siliqua</i>	2	4	0.40

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188101	<i>Nitzschia solita</i>	1	0	0.00
188101	<i>Nitzschia tryblionella</i>	2	0	0.00
188101	<i>Nitzschia valdestriata</i>	2	17	1.71
188101	<i>Pleurosigma delicatulum</i>	2	5	0.50
188101	<i>Rhoicosphenia curvata</i>	3	6	0.60
188101	<i>Rhopalodia gibba</i>	2	3	0.30
188101	<i>Rhopalodia operculata</i>	1	0	0.00
188101	<i>Stauroneis tackei</i>	2	1	0.10
188101	<i>Stephanodiscus hantzschii</i>	2	15	1.51
188101	<i>Stephanodiscus minutulus</i>	2	2	0.20
188101	<i>Surirella brebissonii</i>	2	0	0.00
188101	<i>Synedra fasciculata</i>	2	35	3.53
188101	<i>Synedra pulchella</i>	2	0	0.00

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188201	<i>Achnanthes delicatula</i>	2	0	0.00
188201	<i>Achnanthes minutissima</i>	3	31	3.16
188201	<i>Amphora libyca</i>	3	2	0.20
188201	<i>Bacillaria paradoxa</i>	2	1	0.10
188201	<i>Caloneis bacillum</i>	2	4	0.41
188201	<i>Caloneis schumanniana</i>	2	2	0.20
188201	<i>Cocconeis placentula</i>	3	1	0.10
188201	<i>Cyclotella meneghiniana</i>	2	0	0.00
188201	<i>Cymatopleura solea</i>	2	2	0.20
188201	<i>Diploneis puella</i>	2	4	0.41
188201	<i>Epithemia sorex</i>	3	6	0.61
188201	<i>Epithemia turgida</i>	3	1	0.10
188201	<i>Fragilaria elliptica</i>	2	12	1.22
188201	<i>Gomphonema parvulum</i>	1	23	2.35
188201	<i>Gyrosigma macrum</i>	2	9	0.92
188201	<i>Gyrosigma spencerii</i>	2	3	0.31
188201	<i>Navicula caterva</i>	2	16	1.63
188201	<i>Navicula cincta</i>	1	3	0.31
188201	<i>Navicula circumtexta</i>	1	6	0.61
188201	<i>Navicula erifuga</i>	2	17	1.73
188201	<i>Navicula goersii</i>	2	6	0.61
188201	<i>Navicula gregaria</i>	2	3	0.31
188201	<i>Navicula halophila</i>	2	3	0.31
188201	<i>Navicula menisculus</i>	2	1	0.10
188201	<i>Navicula ommissa</i>	1	6	0.61
188201	<i>Navicula pygmaea</i>	2	6	0.61
188201	<i>Navicula salinicola</i>	1	17	1.73
188201	<i>Navicula slesvicensis</i>	2	2	0.20
188201	<i>Navicula tenelloides</i>	1	4	0.41
188201	<i>Navicula veneta</i>	1	26	2.65
188201	<i>Nitzschia acicularis</i>	2	2	0.20
188201	<i>Nitzschia aequorea</i>	2	70	7.14
188201	<i>Nitzschia apiculata</i>	2	5	0.51
188201	<i>Nitzschia archibaldii</i>	2	4	0.41
188201	<i>Nitzschia capitellata</i>	2	30	3.06
188201	<i>Nitzschia dissipata</i>	3	4	0.41
188201	<i>Nitzschia filiformis</i>	2	3	0.31
188201	<i>Nitzschia flexoides</i>	2	2	0.20
188201	<i>Nitzschia frustulum</i>	2	162	16.53
188201	<i>Nitzschia gracilis</i>	2	2	0.20
188201	<i>Nitzschia hungarica</i>	2	7	0.71
188201	<i>Nitzschia inconspicua</i>	2	6	0.61
188201	<i>Nitzschia liebetruthii</i>	2	66	6.73
188201	<i>Nitzschia microcephala</i>	1	4	0.41
188201	<i>Nitzschia palea</i>	1	163	16.63
188201	<i>Nitzschia paleacea</i>	2	132	13.47
188201	<i>Nitzschia perspicua</i>	1	2	0.20
188201	<i>Nitzschia reversa</i>	2	27	2.76
188201	<i>Nitzschia sigmoidea</i>	3	1	0.10
188201	<i>Nitzschia siliqua</i>	2	4	0.41
188201	<i>Nitzschia solita</i>	1	4	0.41
188201	<i>Nitzschia sublinearis</i>	2	2	0.20
188201	<i>Nitzschia valdecostata</i>	2	2	0.20
188201	<i>Nitzschia valdestriata</i>	2	4	0.41
188201	<i>Pinnularia microstauron</i>	2	0	0.00
188201	<i>Pleurosigma delicatulum</i>	2	1	0.10
188201	<i>Rhoicosphenia curvata</i>	3	3	0.31
188201	<i>Rhopalodia gibba</i>	2	8	0.82
188201	<i>Stephanodiscus hantzschii</i>	2	2	0.20
188201	<i>Surirella brebissonii</i>	2	2	0.20

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188201	<i>Synedra delicatissima</i>	2	1	0.10
188201	<i>Synedra famelica</i>	2	2	0.20
188201	<i>Synedra fasciculata</i>	2	36	3.67
188201	<i>Synedra pulchella</i>	2	0	0.00

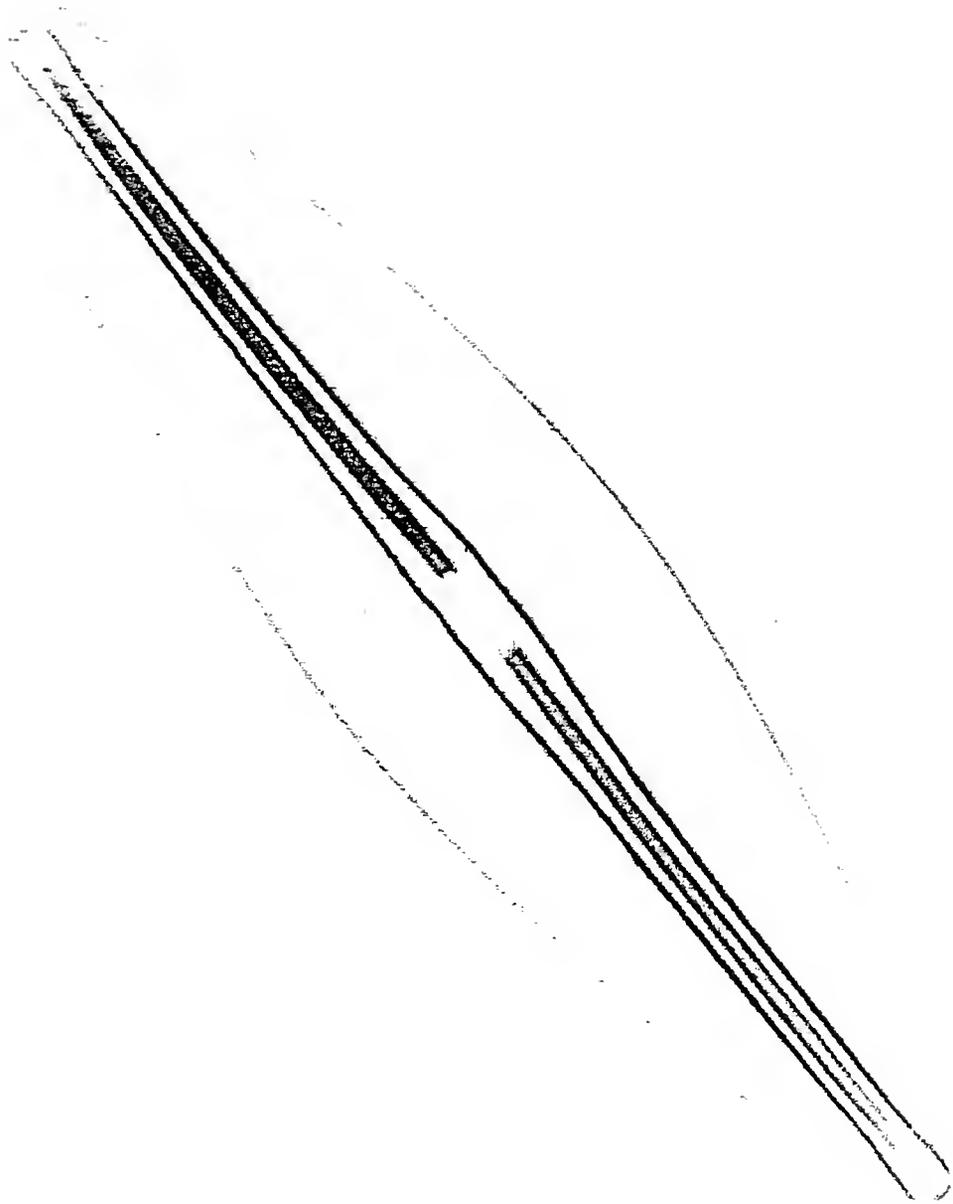
Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188301	<i>Achnanthes delicatula</i>	2	2	0.22
188301	<i>Achnanthes lanceolata</i>	2	3	0.33
188301	<i>Achnanthes minutissima</i>	3	35	3.84
188301	<i>Amphora veneta</i>	1	1	0.11
188301	<i>Caloneis bacillum</i>	2	14	1.54
188301	<i>Cocconeis pediculus</i>	3	0	0.00
188301	<i>Cyclotella atomus</i>	2	4	0.44
188301	<i>Cyclotella meneghiniana</i>	2	4	0.44
188301	<i>Cymbella pusilla</i>	1	1	0.11
188301	<i>Diploneis puella</i>	2	1	0.11
188301	<i>Entomoneis alata</i>	2	2	0.22
188301	<i>Epithemia adnata</i>	2	2	0.22
188301	<i>Epithemia sorex</i>	3	4	0.44
188301	<i>Fragilaria elliptica</i>	2	3	0.33
188301	<i>Gomphonema clavatum</i>	2	1	0.11
188301	<i>Gomphonema gracile</i>	2	2	0.22
188301	<i>Gomphonema parvulum</i>	1	26	2.85
188301	<i>Gyrosigma macrum</i>	2	19	2.08
188301	<i>Gyrosigma spencerii</i>	2	0	0.00
188301	<i>Navicula capitata</i>	2	3	0.33
188301	<i>Navicula caterva</i>	2	8	0.88
188301	<i>Navicula cincta</i>	1	3	0.33
188301	<i>Navicula cuspidata</i>	2	1	0.11
188301	<i>Navicula erifuga</i>	2	1	0.11
188301	<i>Navicula gregaria</i>	2	15	1.64
188301	<i>Navicula halophila</i>	2	4	0.44
188301	<i>Navicula muralis</i>	1	2	0.22
188301	<i>Navicula salinicola</i>	1	4	0.44
188301	<i>Navicula tenelloides</i>	1	8	0.88
188301	<i>Navicula tenera</i>	1	2	0.22
188301	<i>Navicula veneta</i>	1	11	1.21
188301	<i>Nitzschia acicularis</i>	2	2	0.22
188301	<i>Nitzschia aequorea</i>	2	68	7.46
188301	<i>Nitzschia apiculata</i>	2	3	0.33
188301	<i>Nitzschia archibaldii</i>	2	8	0.88
188301	<i>Nitzschia capitellata</i>	2	8	0.88
188301	<i>Nitzschia debilis</i>	2	2	0.22
188301	<i>Nitzschia dissipata</i>	3	10	1.10
188301	<i>Nitzschia filiformis</i>	2	10	1.10
188301	<i>Nitzschia flexa</i>	2	1	0.11
188301	<i>Nitzschia frustulum</i>	2	169	18.53
188301	<i>Nitzschia gracilis</i>	2	2	0.22
188301	<i>Nitzschia hungarica</i>	2	2	0.22
188301	<i>Nitzschia incognita</i>	2	39	4.28
188301	<i>Nitzschia liebetruthii</i>	2	43	4.71
188301	<i>Nitzschia microcephala</i>	1	4	0.44
188301	<i>Nitzschia palea</i>	1	97	10.64
188301	<i>Nitzschia paleacea</i>	2	81	8.88
188301	<i>Nitzschia perspicua</i>	1	2	0.22
188301	<i>Nitzschia reversa</i>	2	22	2.41
188301	<i>Nitzschia siliqua</i>	2	5	0.55
188301	<i>Nitzschia solita</i>	1	4	0.44
188301	<i>Nitzschia valdecostata</i>	2	2	0.22
188301	<i>Nitzschia valdestriata</i>	2	21	2.30
188301	<i>Pinnularia microstauron</i>	2	1	0.11
188301	<i>Pleurosigma delicatulum</i>	2	11	1.21
188301	<i>Rhoicosphenia curvata</i>	3	29	3.18
188301	<i>Rhopalodia brebissonii</i>	1	0	0.00
188301	<i>Rhopalodia gibba</i>	2	10	1.10
188301	<i>Surirella brebissonii</i>	2	3	0.33

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188301	<i>Synedra fasciculata</i>	2	66	7.24
188301	<i>Thalassiosira pseudonana</i>	2	1	0.11

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188401	<i>Achnanthes lanceolata</i>	2	2	0.22
188401	<i>Achnanthes minutissima</i>	3	11	1.20
188401	<i>Amphipleura pellucida</i>	2	1	0.11
188401	<i>Amphora libyca</i>	3	2	0.22
188401	<i>Amphora pediculus</i>	3	0	0.00
188401	<i>Amphora veneta</i>	1	1	0.11
188401	<i>Bacillaria paradoxa</i>	2	6	0.66
188401	<i>Caloneis bacillum</i>	2	14	1.53
188401	<i>Cyclotella atomus</i>	2	6	0.66
188401	<i>Cyclotella meneghiniana</i>	2	17	1.86
188401	<i>Diploneis puella</i>	2	7	0.77
188401	<i>Entomoneis paludosa</i>	2	1	0.11
188401	<i>Epithemia adnata</i>	2	1	0.11
188401	<i>Epithemia sorex</i>	3	3	0.33
188401	<i>Epithemia turgida</i>	3	0	0.00
188401	<i>Fragilaria elliptica</i>	2	6	0.66
188401	<i>Gomphonema clavatum</i>	2	2	0.22
188401	<i>Gomphonema gracile</i>	2	11	1.20
188401	<i>Gomphonema parvulum</i>	1	13	1.42
188401	<i>Navicula caterva</i>	2	6	0.66
188401	<i>Navicula circumtexta</i>	1	0	0.00
188401	<i>Navicula erifuga</i>	2	35	3.83
188401	<i>Navicula gregaria</i>	2	1	0.11
188401	<i>Navicula halophila</i>	2	1	0.11
188401	<i>Navicula omissa</i>	1	3	0.33
188401	<i>Navicula pygmaea</i>	2	0	0.00
188401	<i>Navicula radiosa</i>	3	1	0.11
188401	<i>Navicula recens</i>	2	0	0.00
188401	<i>Navicula salinicola</i>	1	6	0.66
188401	<i>Navicula veneta</i>	1	15	1.64
188401	<i>Nitzschia acicularis</i>	2	8	0.88
188401	<i>Nitzschia aequorea</i>	2	14	1.53
188401	<i>Nitzschia amphibia</i>	2	4	0.44
188401	<i>Nitzschia apiculata</i>	2	2	0.22
188401	<i>Nitzschia archibaldii</i>	2	10	1.09
188401	<i>Nitzschia capitellata</i>	2	2	0.22
188401	<i>Nitzschia dissipata</i>	3	42	4.60
188401	<i>Nitzschia filiformis</i>	2	127	13.89
188401	<i>Nitzschia frustulum</i>	2	65	7.11
188401	<i>Nitzschia hungarica</i>	2	8	0.88
188401	<i>Nitzschia incognita</i>	2	10	1.09
188401	<i>Nitzschia inconspicua</i>	2	3	0.33
188401	<i>Nitzschia liebetruthii</i>	2	17	1.86
188401	<i>Nitzschia palea</i>	1	77	8.42
188401	<i>Nitzschia paleacea</i>	2	62	6.78
188401	<i>Nitzschia recta</i>	3	1	0.11
188401	<i>Nitzschia reversa</i>	2	176	19.26
188401	<i>Nitzschia sigmoidea</i>	3	0	0.00
188401	<i>Nitzschia solita</i>	1	3	0.33
188401	<i>Nitzschia valdestriata</i>	2	1	0.11
188401	<i>Pleurosigma delicatulum</i>	2	8	0.88
188401	<i>Rhoicosphenia curvata</i>	3	14	1.53
188401	<i>Rhopalodia gibba</i>	2	20	2.19
188401	<i>Rhopalodia operculata</i>	1	5	0.55
188401	<i>Simonsenia delognei</i>	2	2	0.22
188401	<i>Stauroneis tackei</i>	2	1	0.11
188401	<i>Surirella brebissonii</i>	2	3	0.33
188401	<i>Synedra delicatissima</i>	2	8	0.88
188401	<i>Synedra fasciculata</i>	2	47	5.14
188401	<i>Synedra pulchella</i>	2	0	0.00

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188401	Thalassiosira weissflogii	2	2	0.22

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
188501	<i>Achnanthes delicatula</i>	2	1	0.11
188501	<i>Achnanthes lanceolata</i>	2	2	0.22
188501	<i>Achnanthes minutissima</i>	3	55	6.00
188501	<i>Amphora inariensis</i>	3	4	0.44
188501	<i>Amphora pediculus</i>	3	14	1.53
188501	<i>Amphora veneta</i>	1	1	0.11
188501	<i>Bacillaria paradoxa</i>	2	5	0.55
188501	<i>Caloneis bacillum</i>	2	16	1.75
188501	<i>Cyclotella atomus</i>	2	0	0.00
188501	<i>Cyclotella meneghiniana</i>	2	3	0.33
188501	<i>Diploneis puella</i>	2	1	0.11
188501	<i>Epithemia adnata</i>	2	3	0.33
188501	<i>Epithemia soresx</i>	3	7	0.76
188501	<i>Epithemia turgida</i>	3	2	0.22
188501	<i>Fragilaria elliptica</i>	2	19	2.07
188501	<i>Gomphonema intricatum</i>	3	2	0.22
188501	<i>Gomphonema parvulum</i>	1	10	1.09
188501	<i>Gyrosigma macrum</i>	2	1	0.11
188501	<i>Gyrosigma spencerii</i>	2	0	0.00
188501	<i>Mastogloia elliptica</i>	2	0	0.00
188501	<i>Navicula capitata</i>	2	3	0.33
188501	<i>Navicula caterva</i>	2	2	0.22
188501	<i>Navicula erifuga</i>	2	14	1.53
188501	<i>Navicula gregaria</i>	2	3	0.33
188501	<i>Navicula halophila</i>	2	2	0.22
188501	<i>Navicula omissa</i>	1	6	0.66
188501	<i>Navicula pelliculosa</i>	1	2	0.22
188501	<i>Navicula radiosa</i>	3	0	0.00
188501	<i>Navicula reichardtiana</i>	2	2	0.22
188501	<i>Navicula salinicola</i>	1	28	3.06
188501	<i>Navicula vandamii</i>	2	2	0.22
188501	<i>Navicula veneta</i>	1	9	0.98
188501	<i>Nitzschia acicularis</i>	2	2	0.22
188501	<i>Nitzschia aequorea</i>	2	74	8.08
188501	<i>Nitzschia amphibia</i>	2	2	0.22
188501	<i>Nitzschia apiculata</i>	2	4	0.44
188501	<i>Nitzschia archibaldii</i>	2	22	2.40
188501	<i>Nitzschia dissipata</i>	3	11	1.20
188501	<i>Nitzschia filiformis</i>	2	24	2.62
188501	<i>Nitzschia frustulum</i>	2	130	14.19
188501	<i>Nitzschia hungarica</i>	2	1	0.11
188501	<i>Nitzschia incognita</i>	2	6	0.66
188501	<i>Nitzschia inconspicua</i>	2	11	1.20
188501	<i>Nitzschia liebetruthii</i>	2	1	0.11
188501	<i>Nitzschia palea</i>	1	173	18.89
188501	<i>Nitzschia paleacea</i>	2	80	8.73
188501	<i>Nitzschia perminuta</i>	3	1	0.11
188501	<i>Nitzschia reversa</i>	2	60	6.55
188501	<i>Nitzschia sociabilis</i>	2	1	0.11
188501	<i>Nitzschia solita</i>	1	2	0.22
188501	<i>Nitzschia tryblionella</i>	2	0	0.00
188501	<i>Nitzschia valdecostata</i>	2	9	0.98
188501	<i>Nitzschia valdestriata</i>	2	32	3.49
188501	<i>Pinnularia microstauron</i>	2	1	0.11
188501	<i>Pleurosigma delicatulum</i>	2	12	1.31
188501	<i>Rhoicosphenia curvata</i>	3	8	0.87
188501	<i>Rhopalodia gibba</i>	2	9	0.98
188501	<i>Rhopalodia operculata</i>	1	3	0.33
188501	<i>Surirella brebissonii</i>	2	0	0.00
188501	<i>Synedra fasciculata</i>	2	18	1.97



Hannaea

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March 21, 2000

Ms. Carol Endicott
Monitoring and Data Management Bureau
Montana Department of Environmental Quality
P.O. Box 200901
Helena, Montana 59620-0901

Re: Box Elder Creek and Musselshell River Periphyton Reports
DEQ Contract No. 200012

Carol,

Enclosed are my reports on Box Elder Creek and the Musselshell River, based on samples submitted by the Riparian and Wetland Research Program of The University of Montana. I talked to Amy Chadwick and she said that these were separate studies, so I did a separate report on each one.

These projects were very instructive. Box Elder Creek is an intermittent stream and the samples were collected only from pool edges. The periphyton indicated that all of the sites were moderately impaired, most frequently by siltation. Among the impaired sites was the upstream reference site--the only site where riparian habitat was in decent shape. The Musselshell River is a perennial stream and the samples were collected only from rocks in riffles. The periphyton indicated that all of the sites fully supported their aquatic life uses, whereas riparian habitat was rated as partly at risk at all sites due to sparse vegetation and exotic species.

From all of this I would conclude the following: (1) periphyton metrics are relatively insensitive to riparian condition (unless riparian condition has a measurable effect on water quality); (2) excessive sedimentation in perennial, high energy prairie streams (e.g., the Musselshell River) can be detected only by gathering a composite, multi-habitat sample from riffles, runs, and pools (per MDEQ SOPs); and (3) separate sets of biocriteria may need to be developed for perennial vs. intermittent prairie streams.

Sincerely,

Loren Bahls

Loren L. Bahls, Ph.D.
Phycologist

P.S. Thanks very much for the assessment information on prairie streams. It will be very helpful. L